PHASE TRANSFORMATIONS INDUCED BY IRRADIATION WITH IONS IN β Cu-Zn-Al SINGLE CRYSTALS

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***Abstract*-- Single crystals of β Cu-Zn-Al alloys were irradiated with 30 keV Ar ions at room temperature to fluences in the range of 1 to 6 displacements per atom (dpa). The microstructural changes induced by the irradiation were investigated with transmission electron microscopy. Specimens with two different surface orientations, $(100)_\beta$ and $(011)_\beta$, were studied. In specimens with $(100)_\beta$ surface orientation a new phase with a hexagonal close packed structure was formed due to the ion irradiation. The orientation relationship with the matrix was of the type:**

$$(0001)_{Hex} \parallel (0\,\bar{1}\,1)_\beta \;;\; [1\,\bar{1}\,0\,0]_{Hex} \parallel [011]_\beta$$

In specimens with $(011)_\beta$ surface orientation, the hexagonal structure was not observed. Instead, small precipitates of the γ phase with a mean size of 8 nm were found. The results are discussed in comparison with previous ion irradiation experiments and with similar phase transformations occurring in β Cu-Zn-Al alloys.

***Keywords*-- Radiation effects, Cu-Zn-Al alloys, transmission electron microscopy, phase transformations, phase stability.**

I. INTRODUCTION

Phase stability in Cu-Zn-Al alloys is related to the electron concentration, that is, the number of conduction electrons per atom (e/a). At an e/a around 1.5, the equilibrium β phase at high temperature has a disordered body centered cubic (bcc) structure. At a lower e/a the α phase with a disordered face centered cubic (fcc) structure is found and at higher e/a the γ phase is formed, with a complex cubic structure.

On cooling the β phase from high temperatures, two ordering transformations occur: at about 800 K the B2 structure is formed which involves the ordering of nearest neighbours. At a lower temperature, which depends on composition, the $L2_1$ structure is formed which involves the ordering of second neighbours. The stability of the β phase at high temperature is due to the high vibrational entropy characteristic of the bcc structure. However, it is possible to retain the β phase at room temperature by quenching or even by air cooling (the latter is only possible at $e/a \approx 1.48$, which corresponds to the maximum stability of the β phase).

The metastable β phase at room temperature presents martensitic (diffusionless) transformations to close packed structures, named 6R, 18R and 2H, which differ in the stacking sequence of the close packed planes. They can be described as a face centered tetragonal (fct) lattice into which regular basal plane stacking faults are introduced every third plane (18R), or every second plane (2H). The 6R structure is that with no stacking faults. The transformation temperature is strongly composition dependent and can be varied between 0 and 400 K. These martensitic phases inherit the atomic order of the β phase. When diffusion is allowed in these phases, the degree of order is modified. This change is accompanied by changes in the lattice parameters and by an increase in the transformation temperature to the β phase. This process has been named stabilisation. More information about the phase stability of the β and martensitic phases can be found in the review by Ahlers (1986).

Irradiation with different kinds of particles (electrons, ions or neutrons) with energies in the keV or MeV range may be used to study phase stability in alloys (Wollenberger, 1994). One effect of irradiation is to introduce a high concentration of point defects, which substantially enhance diffusion. This enhancement may accelerate the evolution towards thermodynamic equilibrium. On the other hand, the flux of point defects to sinks may produce segregation, resulting in nonequilibrium microstructures. It is then possible to obtain information about the phase stability of a system by studying its evolution under irradiation.

Previous ion irradiation experiments in β phase Cu-Zn-Al have been carried out in order to study the influence of irradiation on the martensitic transformation and phase stability in these alloys (Tolley and Abromeit, 1995; Tolley and Abromeit, 1999). The β phase was irradiated at room temperature with a 300 keV Cu ion beam at the Hahn-Meitner Institute in Berlin. The microstructural changes were studied with transmission electron microscopy (TEM). Copper ions were chosen because they are the main component of the alloy. The energy of 300 keV produces an approximately homogeneous damage in a depth of about 100 nm, which is the typical thickness that is studied with TEM. The main results were the following:

a. Second neighbor order was completely destroyed